

International Federation for Heat Treatment and Surface Engineering 20th Congress
Beijing, China, 23-25 October 2012

Failure Analysis and Regeneration Performances Evaluation on Engine Lubricating Oil

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Abstract

To investigate the behavior of failure and recycling of lubricating oils, three sorts of typical 10w-40 lubricating oils used in heavy-load vehicle including the new oil, waste oil and regeneration oil regenerated by self-researched green regeneration technology were selected. The tribology properties were tested by four-ball friction wear tester as well. The results indicated that the performance of anti-extreme pressure of regeneration oil increase by 34.1% compared with the waste one and its load-carrying ability is close to the new oil; the feature of wear spot are better than those of the waste oil and frictional coefficient almost reach the level of the new oil's. As a result, the performance of anti-wear and friction reducing are getting better obviously.

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Selection and peer-review under responsibility of the Chinese Heat Treatment Society

Keywords: Failure lubricating oil; physicochemical properties; tribology.

1. Introduction

Lubricating oil is high value-added product in oil processing industry for the refining craft is complex, the investment of establishing factory is huge and the cost of analysis and evaluation is high. The service performance of new oil usually deteriorates after the long using and it will turn to be the waste oil till which can't meet the operating requirements(GB/T 17145-1997). The recovery and recycling of waste lubricating oil can save the limited resources as well as avoid the environmental pollution. As a result, the phenomenon that the sprinkle, leakage or combustion of waste lubricating oil optionally will be reduced at the present time(Elbashir N. O. et al.,2002;WANG X. L. et al.,2010). According to the statistics, there are almost 5 million vehicles in Beijing and the number will reach 7

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million in the coming 5 years. We assume that the average amount of oil changed from one car for one time is 3.5 liters and the oil change conducted every 5000 kilometers thus the total amount of oil consumption is 2.45×10^7 liters. In fact, there are hundreds of 4S stations in Beijing, it will economize more than 0.5 billion RMB if all the used oil can be recycled.

As to military equipments, which always operate in the outdoor environment of complex road conditions, catastrophic wind and sand or moist circumstance, their lubricating oil lose efficacy for the high contents of contaminants like wear debris, water and colloid substance. As a result, the failure of components occurs which has a seriously bad affection on the maintenance and the service life of equipments. For example, sand, metal wear debris and colloids accelerates the engine's abnormal wear in early time; the contaminated degree of waste lubricating oil is high which cause that the oil gets deep black and smells irritating; water seepage occurs in engine worsen the emulsification problem which causes the serious corrosion in engine components such as bearing shells. With the determination of military strategic policy in new period, the scientific process of armored equipment maintenance support system accelerated. With the development of lubrication science and technology, it has great economic and military significance that the regeneration of engine lubricating oil replaced from military equipments for environmental protection, resources utilization and improvement of the battle effectiveness.

Based on this, a typical lubricating oil replaced from a heavy vehicle diesel engine was taken as the research object, the oil samples have been regenerated by utilizing the waste lubricating oil green regenerated technology which developed independently. The failure and regeneration behaviors of lubricating oil were studied through the evaluation of the main physical and chemical properties and tribological performance. As a result, the reliable experimental data that for the rational utilizing of lubricating oil and extension of the engine's service life would be provided.

2. Experimental Methods

2.1. Experimental Oil

The study objects were three CD 10 W - 40 oil (marked as WO) gathered from one heavy vehicle diesel engine in maintenance process. The oil samples were black and viscous as shown in figure 1. Figure 2 showed the clear regeneration oil (RO) which was the replaced CD 10W-40 oil that has been regenerated (no additive) by utilizing the waste lubricating oil green regenerated technology developed independently. What's more, the properties of waste lubricating oil, regeneration oil and new CD 10 w - 40 product oil (NO) were compared.



Figure 1. Lubricating oil replaced from heavy vehicle in maintenance (WO)

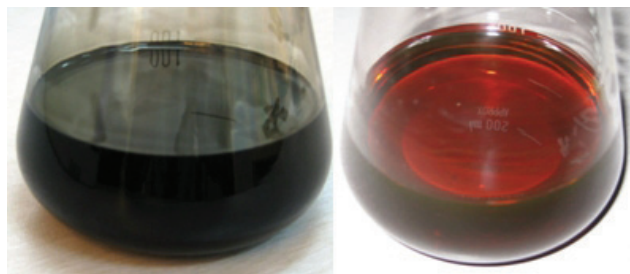


Figure 2. The appearances comparing of WO and RO

2.2. Tribology Performance Evaluation

The friction reducing and anti-wear properties of lubricating oil samples were tested by utilizing MM-10W multi-function friction and wear tester (Jinan macro assay test instrument co., LTD.) according to GB3142-82. The main parameters of the test experiment were shown in table 1.

Table 1. The test experimental parameters

Test	Rotational Speed (r/min)	Load (N)	Time (min)	Temperature
Test 1	600	588	30	Room-temperature
Test 2	1000	588	30	Room-temperature

After testing, in order to evaluate the anti-wear property of lubricating oil sample, the wear spot diameter (WSD) of balls were measured by using optical microscope (Shanghai optical instrument co., LTD.) with accuracy of 0.01 mm. The measured diameter was the mean value for the wear spot diameters of three balls. The steel balls used in tests were cleaned for 5 min in the petroleum ether by ultrasonic after the tests. The surface morphology of ball wear spots were analyzed by Quanta 200 s electronic scanning microscope (US FEI Company). At last, The ferrograms which gained by analytical ferrography according to SH/T 0573 were observed by utilizing the Nova Nano SEM 450 (US FEI company) electronic scanning microscope and the pollution degree of waste lubricating oil (WO) were obtained.

3. Test Results and Analysis

The tribological properties of three typical oil samples (NO, WO, RO) were investigated by using four balls experiment. The indicators of tribology performances here talked about mainly contained the properties of anti-wear and friction reducing represented by wear scar diameter and friction coefficient respectively.

Figure 3 showed the wear scar morphology of three typical oil samples under the conditions that the load was 588N and the rotational speed was 600r/min. Comparing that the morphology of the new lubricating oil wear scar was rule-round and smooth surface together with no furrows and deep scratches in figure 3 (a) and (b), Figure 3 (c), (d) showed the waste lubricant wear scar morphology was more irregular, radial elongation and surface damage was more serious. What's more, there were more flaking broken spots and many furrows observed, which indicated that there were so many abnormal wear debris in waste lubricating oil that severe abrasive wear, sliding wear and adhesive wear occurred and resulting in the decrease of anti-wear performance thus the oil has been difficult to play a lubricating role. The existence of a large number of abrasive grains destroyed the lubricating oil film thus the boundary lubrication condition was coming for Friction pairs and the wear degree aggravated(KIM S. S., HWANG H. J., SHIN M. W., et al.,2011;Varenberg M., Halperin G., Etsion I.,2002;PENG Z., Kessissoglou N.,2003). As a result, a large number of furrows and sc ing grain, etc.), particle size bigger (large anomaly grinding grain)(LIU J.J, Li S. ZHOU P. A, et al.,1993). Figure 3 (e) and (f) showed that the wear scar morphology of the regeneration oil sample, wear scar surface has become relatively flat and no obvious breakage. So, the wear types in the experimental process may be normal sliding wear and mild abrasive wear and reached the lubrication performance of new one. The phenomenon above indicated that the various abnormal wear particles which had impact on anti-wear properties of oil were removed thus the waste oil resistant performance has been improved ratches formed in samples' wear spots and the depth of the furrow or the width of scratches were related with abrasive hardness higher (such as Fe₃O₄ grind).

In order to further investigate the anti-wear performance of regeneration oil in a more stringent condition, a group of friction tests were conducted in conditions that load was 588N and the rotational speed was 1000 r/min. The results were shown in figure 4. Figure 4 (a) and (b) were the wear scar morphology of waste oil and wear scar was very irregular overall and the surface was quite rough for some serious adhesive wear appeared on it. Much spalling damage could be a observed in view field, and some studies have suggested that the major wear forms in oil bath friction were adhesive wear and corrosive wear(JIA B. B, TONG-S. L., Liu X.J., et al.,2007).

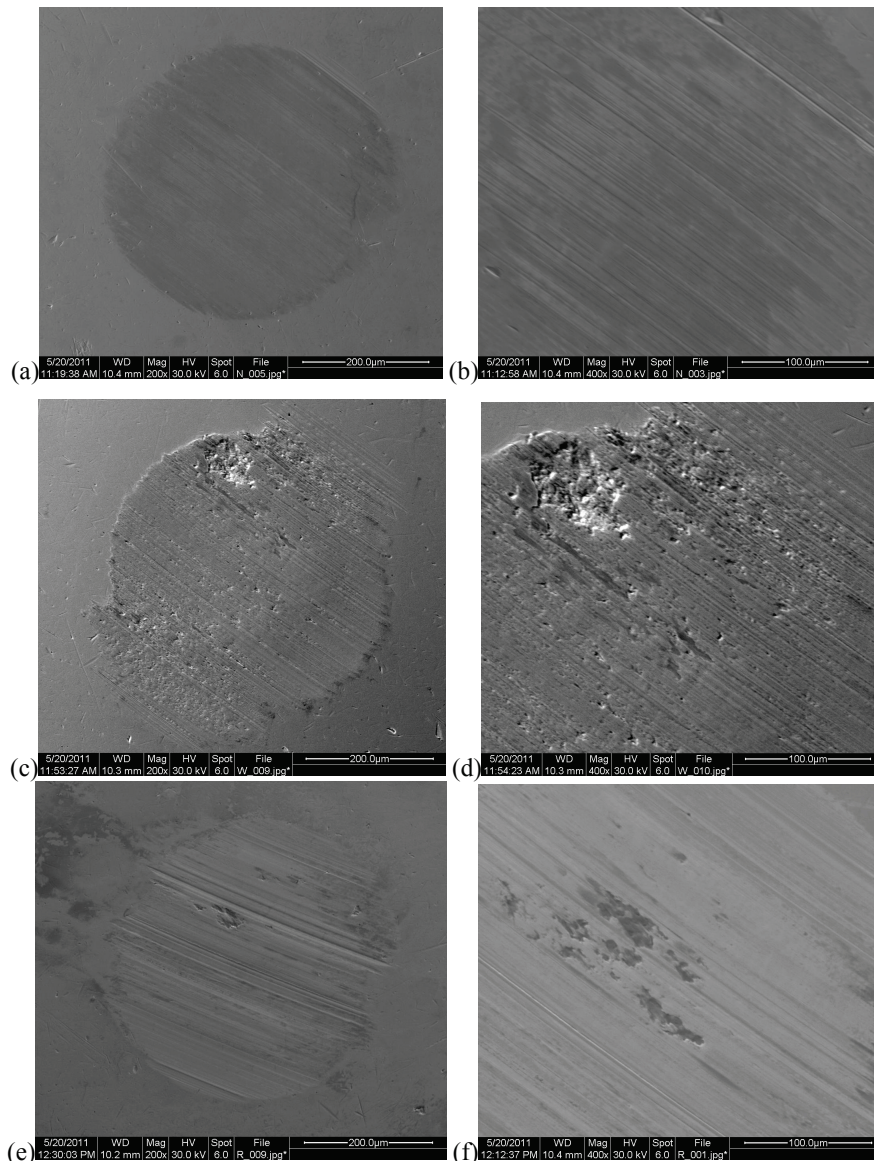


Figure 3 The SEM photos of three samples NO, WO, RO wear spot morphology under the condition that 588N、 600r/min: (a) (b) wear spot morphology of NO; (c) (d) wear spot morphology of WO; (e)(f) wear spot morphology of RO

In addition, Some deep and wide furrow and scratches were also found. The reason why the afore-mentioned phenomenon appeared might lie in the high temperature caused by high-speed operation between the friction pairs which increased the viscosity of lubricating film rapidly and the probability of adhesive wear appearing raised(YUAN C.Q. et al.,2004); Combined with the existence of a large number of abnormal wear debris, which usually were quite solid (most were oxidation of iron series metal particles, such as Fe_2O_3 and Fe_3O_4 , etc.). As a result, they could not only destroy the oil film and lead to the reduction of lubrication effect directly but also could cause some scars such as surface furrow and scratches on the friction pairs surfaces easily(Le´ sniewski T., Krawiec S.,2008). Figure 4 (c) and (d) were wear scar morphology of regeneration lubricating oil, the shape of scars were regular and the surface roughness has greatly improved thus the overall anti-wear performance has been improved.

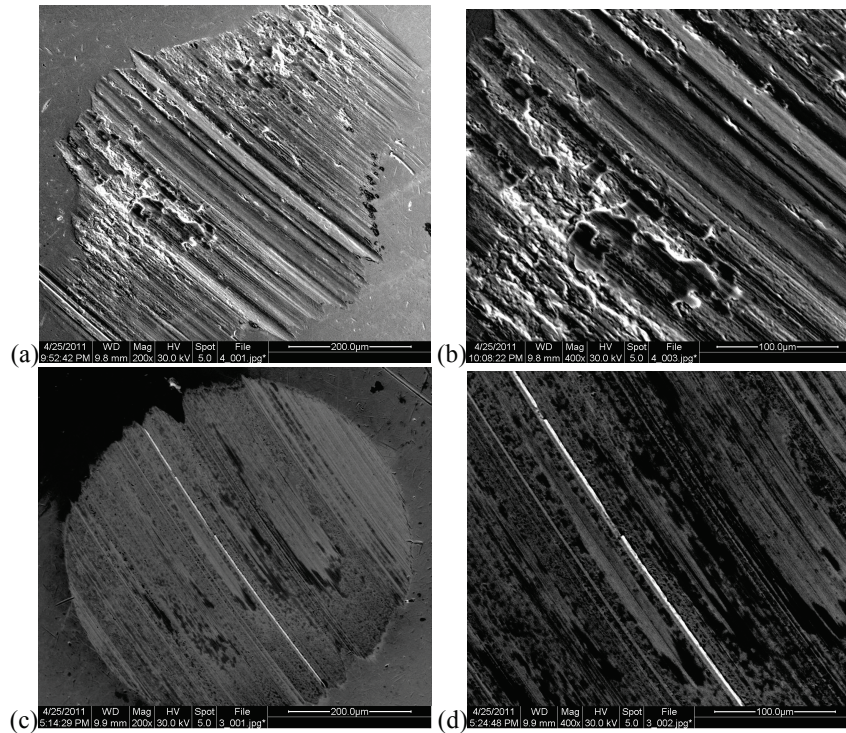


Figure 4. The SEM photos of three samples NO, WO, RO wear spot morphology under the condition that 588N, 1000r/min: (a) (b) wear spot morphology of WO; (c) (d) wear spot morphology of RO

Figure 5 showed some typical abnormal wear debris observed in ferrograms of waste oil obtained by using analytical ferrography. Image (a) showed a bulky debris which was more than 70μm and looked like a piece of wood. Image (b) showed a typical field of view in abnormal wear period for many bulky particles can be seen everywhere. The sizes range from 30 to 100μm. The particles might be the main reason of the decrease of anti-wear performance of the waste oil.

The research showed that the waste lubricating oil green regenerated technology developed independently can effectively improve the anti-wear performance of waste oil.

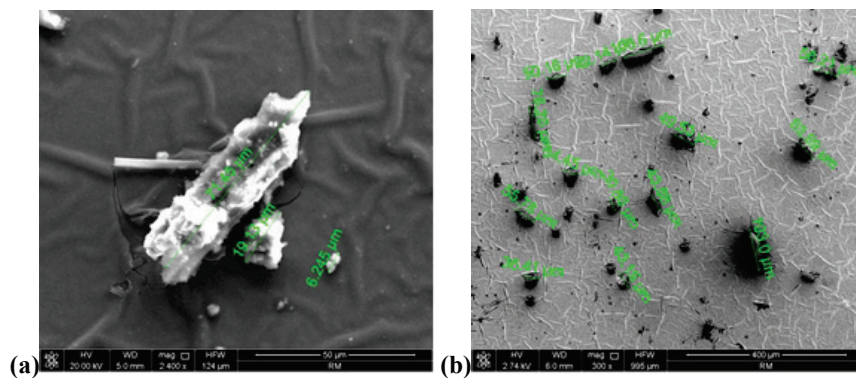


Figure 5. The SEM images of some abnormal wear debris in waste oil

Figure 6 showed the dynamic friction coefficient curves measured in the condition that load was 588N and rotational speed was 600 r/min. As shown, the friction coefficient of waste lubricating oil has been a larger value close to 0.11 and the curve was not smooth for some wave motions existed. The conclusion that the friction reducing performance declined obvious contrasted the new lubricating oil curve easily can be carried out. The curve of regeneration lubricating oil is more smooth than the waste and the mean in 0.095 which almost was closed to the new oil-0.08. It illustrated that the effect of regeneration technology to improve the friction reducing performance of waste lubricating oil was obvious.

Figure 7 showed the dynamic friction coefficient curves measured in the condition that load was 588N and rotational speed was 1000 r/min. As shown, the dynamic friction coefficient curve of waste lubricating oil waved severely and there was a growing trend thus the friction reducing performance degraded seriously. However, the friction coefficient of regeneration lubricating oil has maintained in a relatively low status while the fluctuation was serious, which showing the instability of lubrication performance. There was a possibility of failure finally with the increase of test time. Some reasons for this might be: The wear debris that effecting the lubricating oil's friction reducing performance had been removed, but as a result of no supplement relevant additives, the friction reducing performance in the harsh conditions has not been improved essentially and the possibility of failure would exist for long-term work.

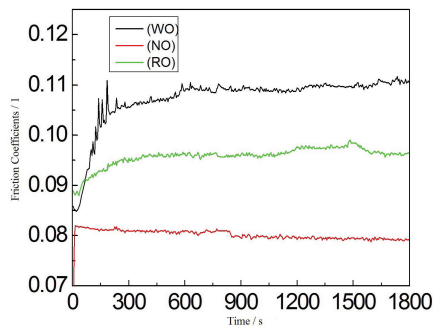


Figure 6. The friction coefficient curves of three lubricating oil samples under the 588N/600R

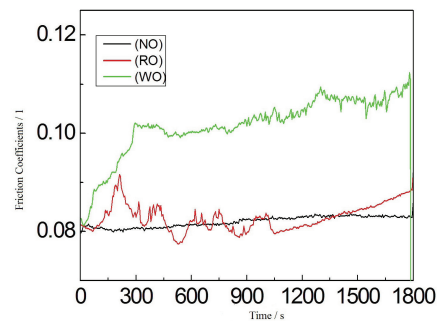


Figure 7. The friction coefficient curves of three lubricating oil samples under the 588N/1000R

4. Conclusions

(1) The tribological experiment results show that: the properties of anti-wear and friction reducing of waste lubricating oil decreased seriously contrast the new oil. Using value has greatly declined; The anti-wear performance has been improved and showed very good effect of regeneration in the two conditions; The friction reducing performance also had increased greatly for the friction reducing performance of regeneration oil improved in test 1 (Load was 588 N and rotational speed was 600 r/min) while which was more seriously fluctuating in test 2 (Load was 588 N and rotational speed was 1000 r/min) and there was a failure might exist.

(2) The waste lubricating oil green regenerated technology developed independently can effectively remove the abnormal composite wear debris which was given priority to the main pollutants in waste lubricating oil, thus the regeneration oil physical and chemical performance will be enhanced and its tribological properties will be improved. Further improvement is that the corresponding additives added into the oil after regeneration treatment so that the friction reducing performance can be improved essentially.

Acknowledgments

The paper is financially supported by 973 Project (2011CB013405).

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